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## **A microstrain comparison of passively fitting screw-retained and cemented titanium frameworks**

de Vasconcellos, Diego Klee ; Kojima, Alberto Noriyuki ; Mesquita, Alfredo Mikail Melo ; Bottino, Marco Antonio ; Özcan, Mutlu

**Abstract:** STATEMENT OF PROBLEM An imprecise fit between frameworks and supporting dental implants in loaded protocols increases the strain transferred to the periimplant bone, which may impair healing or generate microgaps. **PURPOSE** The purpose of this study was to investigate the microstrain between premachined 1-piece screw-retained frameworks (group STF) and screw-retained frameworks fabricated by cementing titanium cylinders to the prefabricated framework (group CTF). This procedure was developed to correct the misfit between frameworks and loaded implants. **MATERIAL AND METHODS** Four internal hexagon cylindrical implants were placed 10 mm apart in a polyurethane block by using the surgical guides of the corresponding implant system. Previously fabricated titanium frameworks (n=10) were divided into 2 groups. In group STF, prefabricated machined frameworks were used (n=5), and, in group CTF, the frameworks were fabricated by using a passive fit procedure, which was developed to correct the misfit between the cast titanium frameworks and supporting dental implants (n=5). Both groups were screw-retained under torque control (10 Ncm). Six strain gauges were placed on the upper surface of the polyurethane block, and 3 strain measurements were recorded for each framework. Data were analyzed with the Student t test ( $\alpha=.05$ ). **RESULTS** The mean microstrain values between the framework and the implants were significantly higher for group STF (2517  $\mu\epsilon$ ) than for group CTF (844  $\mu\epsilon$ ) ( $P<.05$ ). **CONCLUSIONS** Complete-arch implant frameworks designed for load application and fabricated by using the passive fit procedure decreased the strain between the frameworks and implants more than 1 piece prefabricated machined frameworks.

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## **Microstrain comparison of passively fitting screw-retained and cemented titanium frameworks for immediately loaded implants**

### **ABSTRACT**

**Statement of problem.** Precision of fit between frameworks and supporting dental implants in immediately loaded protocols reduces the strain transferred to the peri-implant bone that may impair healing or generate micro-gaps. **Purpose.** This study investigated the microstrain between premachined one-piece screw-retained frameworks (STF) and screw-retained frameworks constructed by the procedure of cementing titanium cylinders to the pre-fabricated framework (CTF), which has been developed for correction of misfit between framework and immediately loaded implants. **Material and methods.** Four internal hex cylindrical implants were placed 10 mm distant to each other in a polyurethane block, using surgical guides of the corresponding implant system. Previously fabricated titanium frameworks (N=10) were distributed into 2 groups. While in group STF, pre-fabricated machined frameworks were used (n=5), in group CTF, the frameworks were constructed by a passive fit procedure, which has been developed for correction of misfit between cast titanium frameworks and supporting dental implants (n=5). **CTF system was cemented first in the final cast and then screw retained to the implants.** Both groups were screw-retained under torque control (10 N/cm). Six strain gauges were placed on the upper surface of the polyurethane block and 3 strain measurements were recorded for each framework. Data were analyzed with the Student's t-test ( $\alpha=.05$ ). **Results.** Mean microstrain values between framework and the implants were significantly higher for STF (2.517  $\mu\epsilon$ ) compared to that of CTF (844  $\mu\epsilon$ ) ( $p=0.05$ ). **Conclusions.** Complete arch implant frameworks designed for immediate load application constructed by the passive fit procedure created less

strain between the framework and the implants than one-piece pre-fabricated machined frameworks.

### **Clinical implications**

Frameworks constructed by a passive fit procedure, which has been developed for correction of misfit between titanium frameworks and supporting dental implants, reduces stress transferred to the peri-implant tissues, compared to pre-fabricated machined frameworks.

## INTRODUCTION

Oral rehabilitation with osseointegrated titanium implants may be regarded as a treatment option with a positive prognosis when properly indicated and planned.<sup>1</sup> In the original protocol for osseointegrated implant borne prosthodontic treatment for the complete arch, implants remain submerged under the soft tissues for a period of 3 to 6 months. In principle, they should heal without influence from occlusal forces or possible bacterial contamination.<sup>1,2</sup> Such forces might interfere with the osseointegration process.<sup>3</sup> In most patients, a complete or partial removable temporary prosthesis is required to reestablish function during this healing period.<sup>3</sup> Use of this type of transitional treatment prostheses was a limitation for some prospective patients to accept when considering this type of treatment.<sup>4,5</sup> Implant therapy might have more appeal for those prospective patients as an alternate treatment option if the implants are loaded immediately after implant surgery.<sup>4,5</sup>

Several protocols for the immediate loading of implants in edentulous jaws have been proposed,<sup>3-7</sup> which allow a patient to wear a fixed prosthesis during the osseointegration period. The reported procedures aim for the goal of a less protracted treatment protocol. Some methods use surgical guides and pre-fabricated prosthodontic frameworks that allow placement of implants and the prosthesis on the same day. Within a few hours after implant surgery, a fixed prosthesis, constructed on a pre-manufactured titanium framework is attached to the implants.

Analysis of the biomechanics of conventional implant-supported rehabilitation, namely two stage implant approach, reveals that any misfit introduced in the prosthesis-implant system may yield stresses that will not be dissipated with time, considering the ankylotic nature of osseointegration.<sup>8</sup> Therefore, misfits may lead to problems, such as screw loosening, fracture of the prosthodontic component or even implant itself and bone loss around the implants.<sup>9</sup>

Therefore, the need for a passively fitting implant prosthesis is essential for maintenance of osseointegration in conventional protocols. However, in the immediate loading procedures, such concepts undergo important alterations. According to Skalak,<sup>10</sup> the static stresses caused by the prosthodontic misfit may be dissipated during the first weeks of osseointegration in the immediate loading procedure, which is not possible with completely osseointegrated implants. When implants are placed, the former lamellar bone present initially maintains the stresses. As this bone is resorbed, the newly formed bone will probably not reinstall the initial stresses. Therefore, the residual stresses caused by prosthodontic misfit may be relieved by the sequence of remodeling processes, which will lead to osseointegration. In that respect, the level of microstrains generated between the framework and implant are significant that is typically measured using strain gauges in simulated settings.<sup>11</sup> One thousand microstrains (1000  $\mu\epsilon$ ) was reported to correlate to a cell elongation of 0.1%.<sup>12</sup> Frost<sup>13</sup> distinguished a minimum effective strain of 500  $\mu\epsilon$  needed for bone maintenance from the supra-physiological strain (>4000  $\mu\epsilon$ ) that would lead to a long-term implant failure due to overload. Higher strains may favor bone healing when applied in the single-step procedure,<sup>14-17</sup> provided that they are within the acceptable levels which would be between 100 $\mu\epsilon$  and 2.000 $\mu\epsilon$ <sup>18</sup>.

The purpose of this study was to investigate the microstrain between premachined one-piece screw-retained frameworks (STF) and premachined screw-retained frameworks constructed by a passive fit procedure (CTF), which has been developed for correction of misfit between framework and supporting dental implants for immediately loaded implants. The null hypothesis tested was that STF and CTF systems would not show significant difference in terms of microstrain.

## MATERIAL AND METHODS

A polyurethane block (F 16, AXSON TECHNOLOGIES, Cergy, France) (35 mm x 125 mm x 45 mm) was used, representing edentulous mandible. A surgical guide template (Speed Master; Conexão Prosthetic Systems, Sao Paulo, Brazil) was attached to the block with 3 temporary stabilization screws. This template has 4 orifices in which a surgeon inserts and removes metal inserts that guide the direction of implant site preparations. These drill guides are identified by different colors, each representing different diameters corresponding to each drill used (silver, pilot drill and 2.0 mm twist drill; blue, 3.0 mm twist drill; yellow, 3.15 mm twist drill; and purple, 3.35 mm twist drill). Preparation for implant placement was gradually increased with the following twist drill diameters: 2.0 mm, 3.0 mm, 3.15 mm, and 3.35 mm. Finally, Four internal hex cylindrical implants (Connect AR 513413; Conexão Prosthetic Systems, Sao Paulo, Brazil) (diameter: 4 mm; length: 13 mm) 10 mm distant to each other were placed on the polyurethane block. The temporary fixation screws and surgical guide were then removed. Abutments were connected to the implants (No: 022001; Conexão Prosthetic Systems) by fastening screws with a mechanical torque wrench (No: 400000; Conexão Prosthetic Systems), calibrated by electronic torque controllers, using 20 Ncm torque. (Fig. 1)

The ten pre-manufactured titanium bars (Fig. 2) employed in this study were distributed as follows: Group 1 (G1): was composed of five 1-piece machined bars (n=5) ready for use (001010 – Conexão Prosthetic Systems – São Paulo, Brazil); Group 2 (G2) comprised five bars (n=5) constructed by the passive fit method (001009 – Conexão Prosthetic Systems – São Paulo, Brazil) (Fig. 3). G2 system was cemented first in the final cast and then screw retained to the implants.

Previously fabricated titanium frameworks (N=10) (Fig. 2) were distributed into 2 groups: While in group STF, pre-fabricated machined frameworks were used (No: 001010; Conexão Prosthetic Systems) (n=5), in group CTF, the frameworks were constructed by the passive fit method (001009; Conexão Prosthetic Systems) (n=5), described as follows: square impression copings for direct impressions with an open tray technique (023001, Conexão Prosthetic Systems) were secured to the abutments. The screws of the impression copings were fastened with a mechanical torque wrench (No: 400000; Conexão Prosthetic Systems) calibrated by electronic torque controllers, using 10 Ncm torque. Auto polymerizing acrylic resin (GC pattern resin; GC Dental Industrial, Tokyo, Japan) was applied to rigidly connect the impression copings. ( 2.0-mm high and 2.0-mm width). Then the acrylic resin splint was sectioned equidistant from the implants with a 0.3mm double-faced diamond disk (40601 001Microdont, São Paulo, Brazil), and the segments were reconnected.

The impression was recorded with addition silicone (Aquasil; Dentsply, Petrópolis, Rio de Janeiro, Brazil) and with an acrylic resin custom open-top tray. The screws of the impression copings were loosened to disengage each impression coping from the implants and the impression was gently removed. Abutment analogues (No: 101001, Conexão Prosthetic Systems) were attached to the impression copings and the impression was poured with dental stone (Durone; Dentsply, Petrópolis, Rio de Janeiro, Brazil) to create the final cast.

Four pre-fabricated titanium cylinders (No: 105015; Conexão Prosthetic Systems) were attached to the analogues of the final cast and were screw tightened using a mechanical torque-controlling device at a pre-load of 10 Ncm (400000; Conexão Prosthetic Systems). The pre-manufactured titanium framework used for this procedure has 4 orifices on its lower surface, which corresponds to the positions of the cylinders secured on the final cast in such a way that



there are no lateral contacts or contact with the upper surface. Alloy primer was applied in the metal surfaces on the internal aspect of the framework orifices and the external aspect of the cylinders (Alloy Primer, Kuraray Medical Inc, Osaka, Japan). A thin and uniform coat of adhesive resin cement (Panavia 21; Kuraray Medical Inc) was placed inside these framework orifices, and the framework was gently seated over the cylinders on the final cast. In order to avoid excess cement into the screw sites, these areas were covered with a thin film of glycerin oxygen inhibition gel (Oxyguard II, Kuraray Medical Inc). Excess material was removed and the cement was photo-polymerized (Optilux 501, Kerr, West Collins Orange, CA; light output: 600 mw/cm<sup>2</sup>) on each site for 40 seconds from a distance of approximately 2 mm according to the manufacturer's instructions. This procedure was repeated for all five bars (n=5) in this group. Cross-section of CTF and STF systems could be viewed in Fig. 3.

For microstrain measurement, 6 strain gauges (PA-06-060CA-120L, Excel Sensors Ltd. Sao Paulo, Brazil) were bonded to the upper surface of the polyurethane block (Fig. 1) with a cyanoacrylate adhesive (Super Bonder, Loctite, Sao Paulo, Sao Paulo, Brazil), 1 mm away from the implant platforms. The strain gauges were numbered from 1 to 6, from left to right. The frameworks were seated on the polyurethane block and the screws (No: 011014, Conexão Prosthetic Systems) were tightened to 10 Ncm with a mechanical torque device (No: 400000, Conexão Prosthetic Systems) (Fig. 4), with screws being secured in following the order: 2 → 3 → 1 → 4 (2 and 3 denoting the central implants and 1 and 4 denoting the terminal implants).<sup>11</sup> The same operator placed all frameworks. The strain gauge device was calibrated at  $\pm 10 \mu\epsilon$  before the specimens were seated on polyurethane block and the screws were tightened. The magnitude of microstrain ( $\mu\epsilon$ ) at each strain gauge was recorded when the fourth screw was tightened. Data on the 6 sensors were amplified and transferred with a signal amplifier (ADS

2000IP, Lynxx, Sao Paulo, Brazil). Microstrain measurements were recorded for 3 times for each framework. The recorded data were analyzed with a software program (AqDados & AqAnalysis, Lynxx).

Statistical analysis was performed using SPSS System 15.0 for Windows (SPSS Inc., Chicago, IL, USA). The data was found to be normally distributed with equal variance (Kolmogorov-Smirnov and Shapiro-Wilk,  $\alpha = 0.05$ ). The means of microstrain values obtained from the two framework designs (CTF, STF) were statistically analyzed by the Student's t-test. P values less than 0.05 were considered to be statistically significant in all tests. Power analysis was performed using a statistical software package (Stata, StataCorp, Texas, USA).

## RESULTS

Mean microstrain values between framework and the implants were significantly higher for STF ( $2.517 \pm 1.553 \mu\epsilon$ ) compared to that of CTF ( $844 \pm 458 \mu\epsilon$ ) ( $P < 0.05$ ). Table I displays the mean values of the 6 strain gauges, for each framework type. Power analysis indicated ...% power with 5 specimens per group.

## DISCUSSION

Based on the significant differences in microstrain generated between the framework and the implants in STF and CTF systems, the null hypothesis tested was rejected.

The present study was an in vitro investigation of the static microstrain measurement from framework to implants after the placement of 2 different pre-manufactured frameworks provided for the immediate load system.<sup>12</sup> The relative elongation of cells may be calculated in microstrain ( $\mu\epsilon$ ), the unit of strain measurement used in the present investigation. CTF system

created less microstrain compared to STF but the values achieved by both systems were far from the physiological threshold ( $>4000 \mu\epsilon$ ) that would possibly lead to a long-term implant failure, according to Frost.<sup>13</sup> On the other hand, according to Smukler-Moncler et al<sup>6</sup> there is a critical threshold of micromotion above which fibrous encapsulation prevails over osseointegration. When the amount of micromotion at the bone-implant interface is maintained beneath this threshold during the healing phase, immediate occlusal loading procedures can be successful. Only excessive micromotion is directly implicated in the formation of fibrous encapsulation. This critical level, however, is not the absence of micromotion as generally interpreted. Instead, the tolerated micro-motion threshold is found to lie somewhere between 50 and 150  $\mu\text{m}$ .<sup>6</sup> The system investigated in the present study comprises a rigid metal structure joining the implants, which should reduce these micromotions, allowing osseointegration to occur.<sup>3,5</sup> Tarnow et al<sup>3</sup> also have recommended a rigid metal structure to avoid micro-motion and in that way provide resistance to forces in all directions. However, the metal-free design of the prostheses during the healing phase does not appear to jeopardize the osseointegration.<sup>7</sup>

Analysis of microstrain values for the individual strain gauges revealed that the mean value for strain gauge no. 2 with the STF system was higher than the physiological threshold. The consequence of this excessive strain at this specific site may not be as harmful for the immediate load protocol as it would be for the conventional protocol. Yet, this aspect needs to be verified in clinical studies.

In an attempt to minimize variations during the study, the same operator performed all laboratory procedures and a calibrated mechanical torque device was used to assure the consistent torque of 10 Ncm during screwing the frameworks before microstrain measurements. The accomplishment of 3 measurements for each specimen in both groups aimed at minimizing

the errors during measurement. As in the study of Inturregui et al<sup>14</sup>, in this investigation also high standard deviation were observed, which may have been the outcome of the high sensitivity of strain gauges compared to the forces generated in the system. This could also be attributed to the in vitro model simulating human bone. Certainly, in the experimental set-up of strain gauge analysis in a static state only, does not simulate the physiologic remodeling that would normally take place in an immediate loading protocol.<sup>15</sup> In the present study, a polyurethane base was used because of its uniform elastic properties, being an isotropic material.<sup>11,15</sup> Moreover, its modulus of elasticity (20 GPa) is similar to that of human bone.<sup>11,16</sup> In vivo, human bone presents a more complex situation when bone remodeling occurs during the healing period,<sup>12</sup> but experimental models may help to grade the materials or systems that deliver more favorable results prior to clinical applications.

The procedure of cementing the titanium cylinders to the pre-fabricated framework (CTF) has been recommended by the manufacturer of the tested system to achieve a better passive fit between the framework and the abutments. The present results reveal that the microstrain values generated by CTF system were nearly 65% less than the values produced in STF. It has to be also noted that a cement interface is at risk overtime due to fatigue load effects leading to loosening and possible compromise of the framework. Therefore, further laboratory studies should submit the bonded structures to thermal and mechanical cycling, simulating the situation found in the oral cavity. Additionally, clinical trials should be report on the long-term safety and efficacy of procedures compared in this study.

## **CONCLUSION**

Complete arch implant frameworks designed for immediate load application constructed by the procedure of cementing the titanium cylinders to the pre-fabricated framework created less strain between the framework and the implants than one-piece pre-fabricated machined frameworks.

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## Figures and Tables

Table I. Mean microstrain values ( $\mu\epsilon$ ) at 6 strain gauges for each framework design (n=5).

Framework type	Strain Gauge Number					
	01	02	03	04	05	06
STF	966.3	4966.6	1090.4	3079.2	3306.6	1694.3
CTF	699.5	1734.3	900.4	663.6	472.3	595.6

## LEGENDS

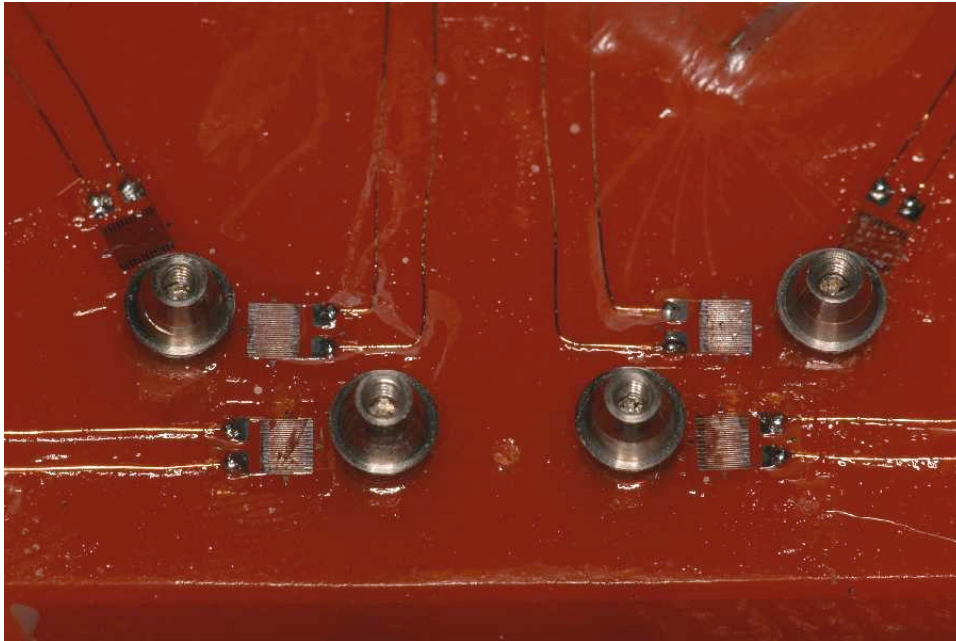


Fig. 1. Polyurethane block with 4 internal hex cylindrical implants and prosthodontic abutments attached. Six strain gauges bonded to upper surface of polyurethane block for microstrain measurements.



Figs. 2. Close-up photo of the external aspect of the pre-fabricated titanium framework for both groups.

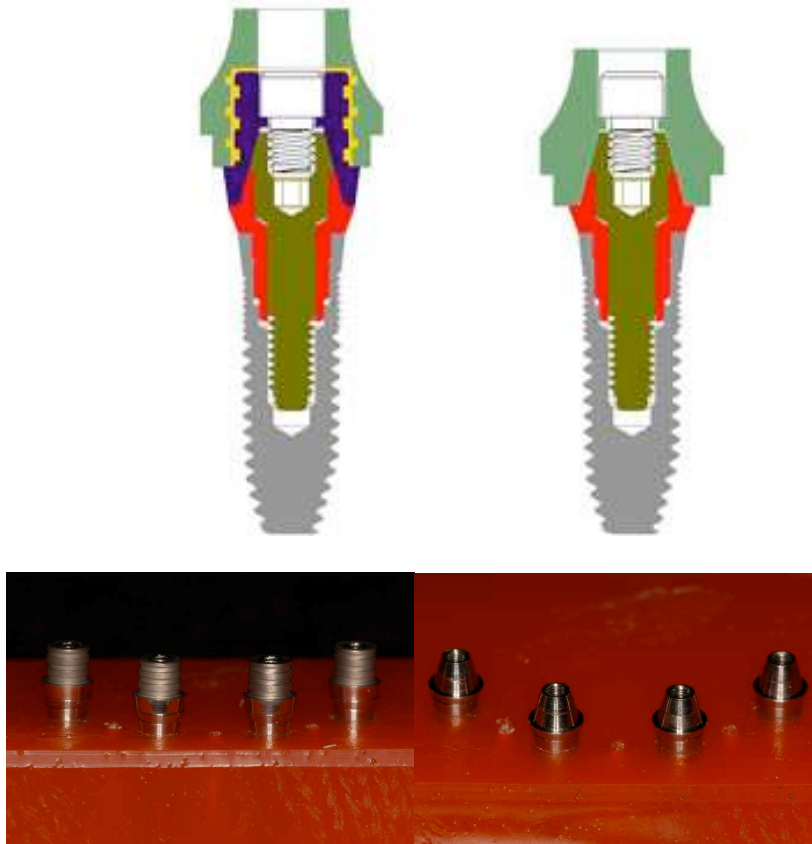


Fig. 3. Left: Cross-section of passively fitting cemented titanium framework with pre-fabricated titanium cylinder screw (blue) fixed on prosthodontic abutment (red and dark green) and cemented (yellow) to the pre-fabricated titanium framework (light green). Right: Cross-section of screw-retained pre-fabricated titanium framework (light green) positioned fixed on the prosthodontic abutment (red and dark green).

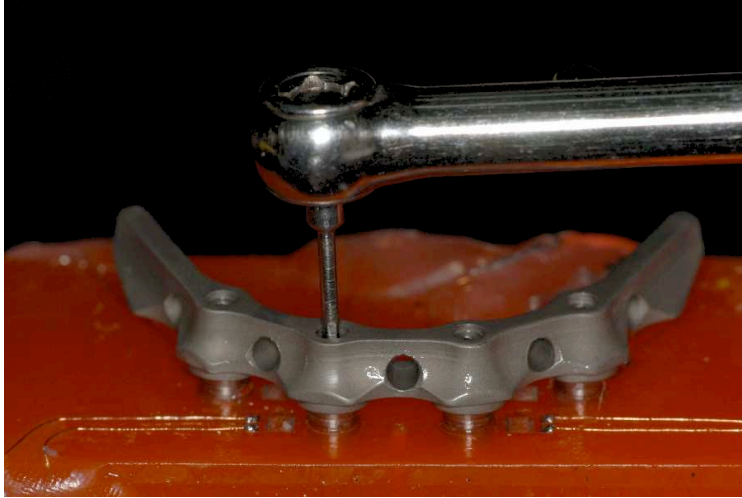


Fig. 4. Screw-retained pre-fabricated titanium frameworks were fixed on the prosthodontic abutments and the screws were tightened to 10 Ncm with mechanical torque device prior to microstrain measurements.